ESD-TDR-63-172 W-5442

DATA RELIABILITY OF THREE BELL A1 MAGNETIC TAPE RECORDING SYSTEMS

TECHNICAL DOCUMENTARY REPORT NO. ESD-TDR-63-172

SEPTEMBER 1963

H. L. Preble

Prepared for

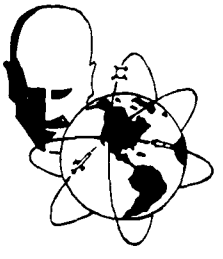
416L (CONTROL AND WARNING SUPPORT SYSTEM)

ELECTRONIC SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

L. G. Hanscom Field, Bedford, Massachusetts



Project 416

Prepared by

THE MITRE CORPORATION
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Contract AF33(600)-39852

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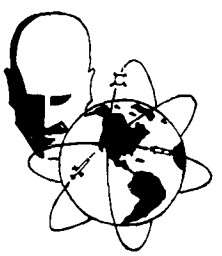

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ABSTRACT

This paper tabulates the results of initial tests conducted to determine the data reliability of three methods of recording Bell A1 digital data on magnetic tape: 1.) the Wollensak Recorder/Reproducer, 2.) an Ampex FR 114B Transport with Ampex FM electronics and "anti-jitter logic," and 3.) an Ampex FR 114B Transport with Ampex FM electronics and Bell A1 DDR/DDT as logic.

The tests were designed only to find an approximate figure for error rate in that the following parameters were held constant: 1.) type tape, 2.) tape age, 3.) position of information across tape (channel effects), 4.) position of information along tape (reel effects), and 5.) word length.

More tests are necessary to determine the effect of these parameters on error rate.

The results show that the three recording systems tested are adequate for their application. The average time between errors was found to be 6 minutes for the Wollensak, 16 minutes for the Ampex/Jitter Logic, and 20 minutes for the Ampex DDR/DDT.

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DATA RELIABILITY OF THREE BELL A1 MAGNETIC TAPE RECORDING SYSTEMS

SECTION I

INTRODUCTION

This report lists the results of tests conducted to determine the data reliability of three systems for recording and reproducing in real time Bell A1 digital data.

The tests were necessary as a check on data reliability. The information about data reliability acquired in this study will prove useful in relation to studies regarding the application of error correcting codes to digital recording techniques, and will also be of interest to system test engineers.

The three methods of recording tested were:

1) the Wollensak Tape Recorder/Reproducer,
2) the Ampex FR-100B Tape Transport with Ampex FM electronics and "anti-jitter logic," and
3) the Ampex FR-100B Tape Transport with Ampex FM electronics and Bell A1 DDR/DDT as logic.

It should be emphasized that this report attempts only to present a "ball park" figure on error rate. The tests were conducted for a particular set of conditions only, and thus each result might not represent the best possible error rate.

The results show that the average time between errors is about 6 minutes for the Wollensak, 16 minutes for the Ampex/Jitter Logic, and 20 minutes for the Ampex - DDR/DDT.

It would be expedient to review the Bell A1 Digital Data Transmission System as used in the SAGE Data Transmission Systems. The Bell A1 Digital Data Transmission System (Figure One), designed by Bell Telephone Laboratory for phone line transmission, consists of three basic parts: the Digital Data Transmitter (DDT), the phone line, the Digital Data Receiver (DDR). SAGE data sources designed for use with Bell A1 equipment put out

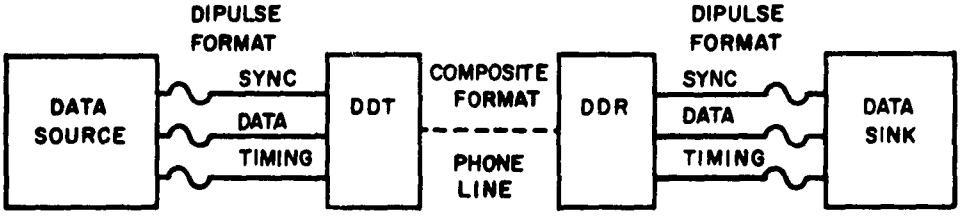

FIGURE ONE

THE BELL AI DIGITAL DATA TRANSMISSION SYSTEM

the dipulse format of three separate signals: Sync, Data and Timing. Bell A1 data sinks receive this three-signal dipulse format. In order to conserve channels, the DDT converts the three-signal dipulse format to a one-signal composite format. One phone line transmits this composite format to the DDR, which serves to convert the composite format back to the three-signal dipulse format.

A typical 16-bit word is illustrated in Figure Two. A "one" on the data line is represented by one full cycle of the 1300-cycle timing wave. Each bipolar pulse is called a dipulse. A "one" in the amplitude-modulated 1950-cycle carrier composite wave is represented by a depression in the envelope.

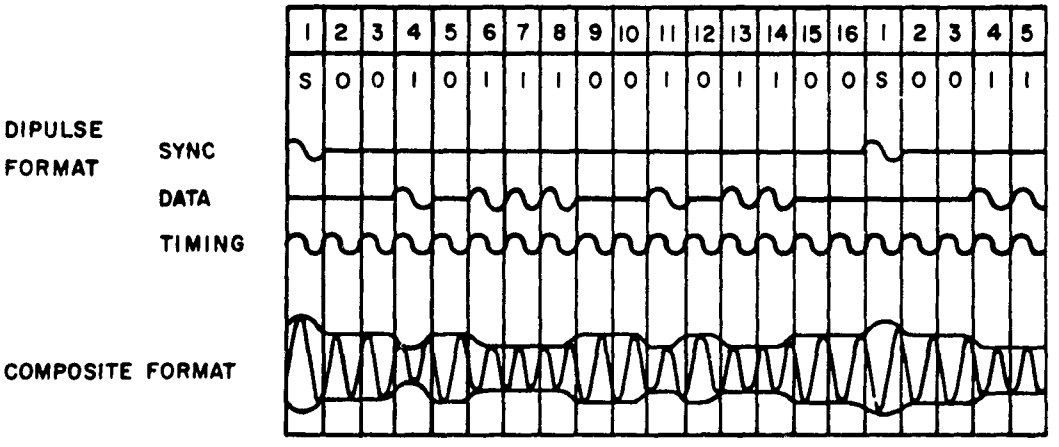

FIGURE TWO

TYPICAL BELL AI SIGNALS

SECTION II

TEST METHODS AND RESULTS

2.1 The Checking Scheme

The same basic checking scheme was used on all three tests. The dipulse output of the recorder was played into pre-programmed checking logic. The checking logic was designed to generate a data reference signal from timing and sync signals, and to compare the data reference signal to the incoming data signal. Errors stopped a Time Interval Meter, which then printed out the elapsed time since the last error. Errors occurring during the print-out time of the printer, that is, within 0.9 second after an error that stopped the timer, were not recorded. A diagram of a typical checking logic hookup is shown in Figure Three.

2.2 The Wollensak Test

The Wollensak Tape Recorder unit is designed to record and reproduce Bell A1 dipulse data to meet the specifications of MITRE TM-2735, except for jitter. It is thus suitable for use with data-using equipment which has an input memory buffer to retime the data, such as the XD-1 computer or an RD-II display console. However, it is a one data-channel recorder, and it has no speed control servo system.

Tests were conducted to determine the approximate data reliability of the machine when tested under the conditions listed in Table One.

The test was conducted as follows: A prechosen 16-bit word was set up on a Bell A1 Word Generator. The test tape was then recorded, and the errors were found by playing the tape back through the checking logic. The tape was recorded with a few seconds of deliberate errors at the beginning of the tape. The start of error-free reproduction then served as a reference for time correlations.

A total of six runs were made after the tape was recorded. The average time between errors for these six runs was six minutes. On the average, at least half of the errors on any given run were correlated to errors which occurred at approximately (±2 seconds) the same time on other runs.

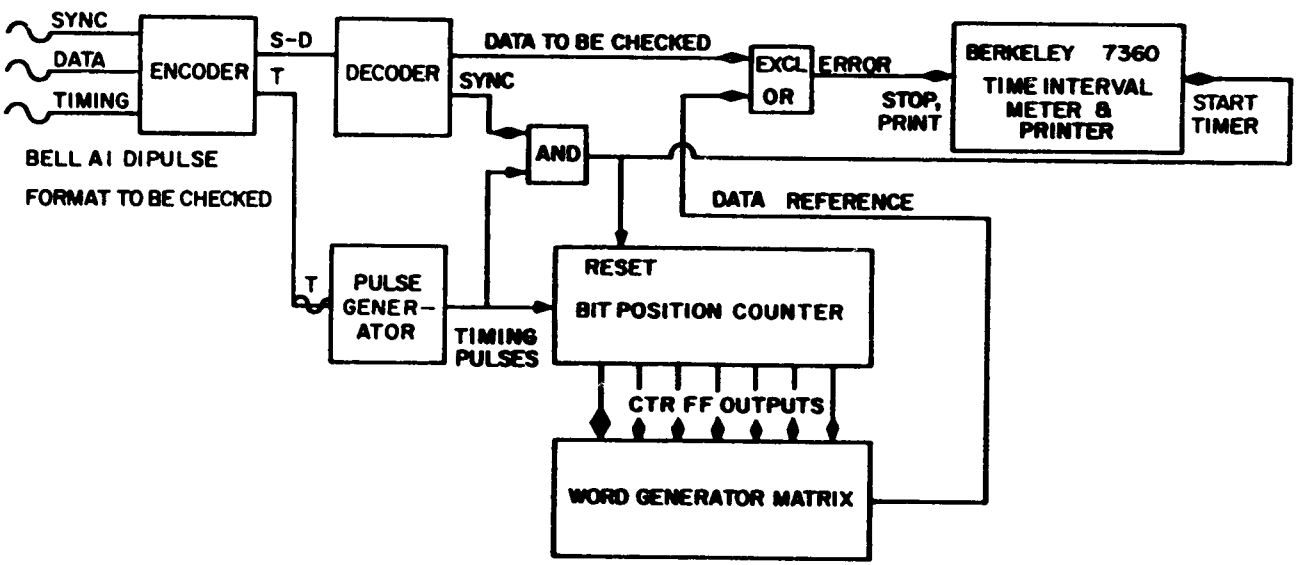

FIGURE THREE

BLOCK DIAGRAM OF TYPICAL CHECKING LOGIC

TABLE ONE
WOLLENSAK TEST RESULTS

TIME	RUN No.						TOTAL ACROSS
	1	2	3	4	5	6	
101	X	X	X	X	X	X	6
184						X	1
226			X				1
301	X						1
572					X		1
807					X		1
912		X					1
1074	X						1
1207	X	X	X		X		4
1426	X	X	X	X	X	X	6
1552					X		1
1577	X						1
1662	X	X	X	X	X	X	6
1663					X		1
1669					X		1
1677		X					1
1703					X		1
2167				X			1
2222				X			1
3061	X	X	X	X	X	X	6
3173	X	X	X	X	X		5
3208	X	X	X				3
3418		X					1
3494	X		X				2
3507				X			1
3513	X	X	X		X		4
3540				X			1
3600	END OF TAPE						
TOTALS DOWN	12	11	10	9	13	5	60

AVERAGE TIME BETWEEN ERRORS — 6 MINUTES
CONDITIONS OF TEST:

TAPE : NEW SCOTCH 200
SPEED : 7 1/2 IPS
WORD : 16 BIT HALF "ONES"
INPUT SIGNAL : NOMINAL LEVEL

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The errors have two components: fixed and random. The random errors are probably due to dust particles or some other random defect, whereas the fixed errors are probably due to errors written on the tape, or to some permanent tape defect such as dropouts.

Table One lists the results of the six runs. The "time" column gives the elapsed time in seconds from the time-reference at which an error occurred on one or more of the runs. An "X" in a run column indicates that an error did occur at the corresponding time on that run. Absence of an "X" indicates no detected error at the corresponding time.

2.3 The Ampex Tests

2.3.1 General

The Ampex transport FR 114B has a 14-channel capability and a servo-controlled speed system.

Coupled with its FM electronics, the Ampex was tested with two methods of recording and reproducing Bell A1 dipulse type data. The two methods tested were the following:

1) the "anti-jitter" system of Valentine and Tanner, and
2) the use of Bell System DDTs and DDRs as encoders and decoders to convert to and from the three-line dipulse format to the one-line composite signal (recording the Bell Composite signal).

It should be emphasized that the test attempted only to determine an approximate figure for data reliability. The testing was not extensive, and many questions are unanswered. Other tests that should be run include determining the error rate as a function of the following variables:

1) position across tape (channel-to-channel),
2) position along tape (reel effects),
3) type of tape,
4) tape wear,

5) input signal at tolerance limits, and

6) word length (sync errors).

2.3.2 Ampex/Jitter Logic Test

Basically, the anti-jitter system is a method of retiming the data to eliminate short-term instability. Two-channels are required on the tape to represent one channel of information: one channel for the dipulse timing signal which also serves as the control track for the tape speed-control servo, and another channel which carries the sync and data composite signals.

It should be remarked that this method has the major limitation that only signals with a common 1300-cycle timing wave can be played back simultaneously. This is because the tape recorder must spew out data in step with the retiming oscillator which also serves as the servo reference signal.

The "composite encoder" circuit, which makes the sync and data composite signal, had a history of being sensitive to bursts of data ones. The circuit was redesigned to correct this problem and as part of this test the old encoder and new encoder were compared.

The composite signal of the "old" encoder was recorded on channel 5, the composite signal of the "new" encoder on channel 9, and the common timing signal on channel 7. Results showed the "new" encoder to be superior to the "old" encoder. The average time between errors was 6 minutes for the old encoders and 16 minutes for the new encoder.

The actual results of the tests are tabulated in Table Two. The time column gives the elapsed time in seconds from a reference of deliberate errors at the beginning of the tape. An "X" in a run column indicates that an error did occur at the corresponding time on that run. Absence of an "X" indicates no detected error at the corresponding time.

2.3.3 Bell Al Ampex DDR/DDT Tests

The Ampex FR-114B tape transport, with Ampex FM electronics and 60-cycle servo speed-control system, was tested using the hookup

TABLE TWO

AMPEX / JITTER LOGIC TEST RESULTS

CHANNEL A (OLD ENCODER)

TIME OF ERROR (SEC)	RUN No. 1	2	3	4	5	TOTAL ACROSS
392		X				1
656	X		X			2
913	X	X	X	X	X	5
1121	X	X	X	X		4
1125	X	X	X	X	X	5
1132	X	X	X	X	X	5
1350			X			1
1690				X		1
1773	X					1
1978		X	X			2
2084					X	1
2317		X	X			2
2482	X	X	X			3
2837					X	1
3248	X	X	X	X	X	5
3832	X	X		X		3
4237			X			1
4296					X	1
4510	X	X	X	X	X	5
4582	X	X	X		X	4
4588				X		1
4605	X					1
4640				X		1
4667		X				1
4739	X					1
4782				X		1
5143				X	X	2
5193	X	X	X	X	X	5
5463				X	X	2
5583				X	X	2
5640	X	X	X	X	X	5
5647	END OF TAPE					
TOTALS DOWN	15	15	15	16	14	75

CHANNEL B (NEW ENCODER)

TIME OF ERROR (SEC)	RUN No. 1	2	3	4	5	6	TOTAL ACROSS
102	X						1
504		X					1
735	X						1
1124			X		X		2
1130	X		X	X	X		4
1206		X	X	X	X		4
1586	X						1
1780		X	X	X	X	X	5
1865		X					1
1970		X					1
2055			X				1
2062				X			1
3263	X						1
3911		X					1
4120						X	1
4247			X				1
4514		X					1
4517	X	X	X	X	X	X	6
5645	END OF TAPE						
TOTALS DOWN	6	8	7	5	5	3	34

AVERAGE TIME BETWEEN ERRORS:

CHANNEL A —— 6 MINUTES

CHANNEL B —— 16 MINUTES

CONDITIONS OF TEST:

TAPE TYPE : AMPEX MI, AGE UNKNOWN

TAPE SPEED : 7—1/2 IPS

WORD : 16 BIT HALF ONES

INPUT SIGNAL : NOMINAL LEVEL

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shown in Figure Four. The Bell A1 DDT and DDR can be thought of as encoders and decoders for the tape system, converting the three-signal dipulse information to a composite signal recorded on one channel on the tape, and for regenerating the Bell A1 three-signal dipulse format when the tape is played back.

The Bell A1 DDT and DDR were rented from NET&T Co., and were physically located in the ESS frame room. Interconnections to the Word Generator, the Tape Electronics, and the Error Counting Logic were made via Telco phone lines from ESS frame room to Lincoln Room B-209.

When the telephone lines were installed, they were tested "back to back;" that is, the tape machine in Figure One was replaced by a short circuit. After the initial adjustments were made, it was noted that the lines were subject to bursts of errors. The average error rate was about one error every two minutes. It was noticed that these errors were a function of the time of day, being less severe during the night hours and more severe during working hours. Thus it was decided to record a tape during the quiet hours to minimize the number of errors. The results are described by Table Three.

TABLE THREE

AMPEX DDR/DDT TEST RESULTS

Time of Error (sec)	Run #1 Nighttime	Run #2 Daytime	Run #3 Daytime
	4758 (5524 end)	3572 3754 4757 5503 (5524 end)	102 1602 3373 3436 3487 3597 4269 ..... 4757 (5525 end)
Totals	1	4	9

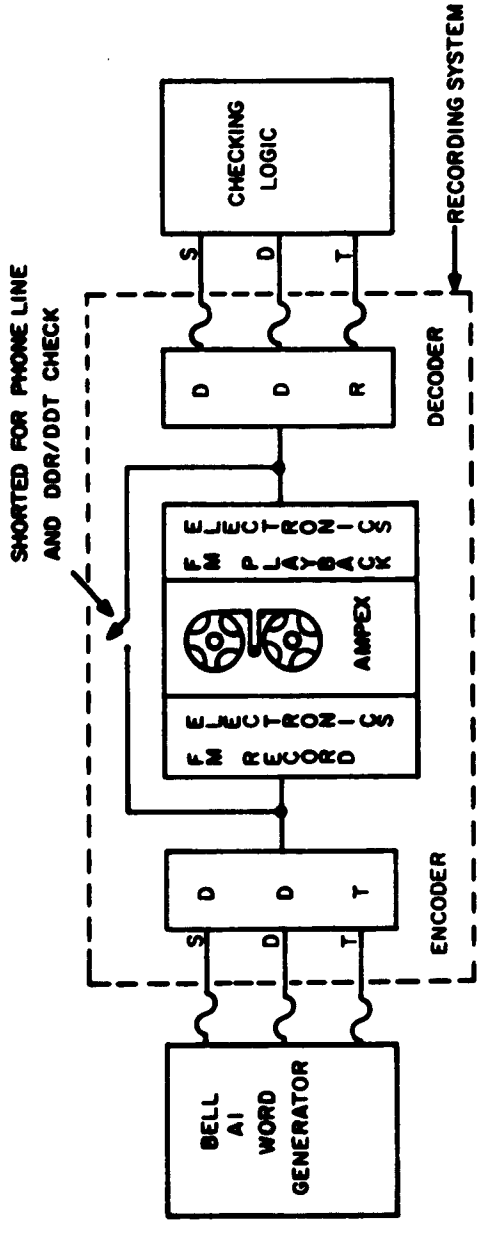

FIGURE FOUR

HOOKUP FOR AMPEX DDR/DDT TEST

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The conditions of the test were as listed in Table Two, except that the tape was recorded and played back simultaneously on Run #1, after working hours. It appears that at 4758 an error occurred. This could have been a fault in the encoder (DDT), or it could have been an actual defect on the tape-dropout, a dustparticle, etc. The two daytime re-runs are unique in the fact that none of the new error times cross-correlate with themselves. The added errors are random in time, which leads to the probable conclusion that a good percentage of them are due to the long phone lines interconnecting the recorder with the DDR/DDT. Thus the average error rate for this type of recording, assuming error-free phone lines, is very good (in this case one per 5525 seconds).

If the random errors are all considered the fault of the tape machine (worst case) the average error-rate is one per 20 minutes.

This test had to be discontinued after three runs because of a high priority demand for the use of the test equipment.

SECTION III

CONCLUSIONS

The tests conducted were successful in that they provided an approximate figure for error rate.

When the Wollensak tape machine was designed it was conceded that an error rate on the order of one word in error per minute would be satisfactory for the checkout of RD-II consoles. The Wollensak amply meets this requirement.

The Ampex dipulses logic system is currently in use in ESS. At times its data reliability has been questioned, and no evidence has been available to show that it is a workable system. These tests have shown the dipulse logic system to have an error rate of one per six minutes with the old encoder, and one per 16 minutes with the new encoder. The new encoder seems to improve the data reliability enough to warrant recommending that it replace all old encoders as soon as possible.

The Ampex and DDR/DDT system seems to be the most promising. In terms of data reliability, the system is better than the jitter logic. If the probable conclusion that a large percentage of the random errors were due to phone line disturbances is correct, then the error rate for this system may approach one per hour or better. Also, this is the best system in terms of economy of tape channels as only one tape channel is required to record one data channel. Furthermore, there is no problem in recording asynchronous data since each channel carries its own timing.

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